

ASSISTANCE TO SURGERY BY MEANS OF INFRARED FUNCTIONAL IMAGING: PRELIMINARY RESULTS

Arcangelo Merla^{1,3}, Luigi Di Donato¹, Gian Luca Romani^{1,2,3}

¹ Dipartimento di Scienze Cliniche e Bioimmagini, Università di Chieti, V.le dei Vestini 13, I-66013 Chieti Scalo (Ch), Italy

² ITAB, Istituto Tecnologie Avanzate Biomediche, Università di Chieti, V.le dei Vestini 13, I-66013 Chieti Scalo (Ch), Italy

³ INFM, Sezione de L'Aquila, Italy

Abstract. Infrared Functional Imaging was used in microsurgery and cardio-surgery operation to assess correct blood re-perfusion after de-clamping of anastomoses. Re-implantation of arm, local sympathectomy and coronary bypass were considered. Moreover, IRFI was used to follow up the restoration of the neurovascular functions thanks to the study of the changes in the thermoregulatory capabilities of the treated district. The study has proved that IRFI can be advantageously used in these fields thanks to its features – non-invasiveness, high temperature, spatial and time resolution and real time availability of data.

Key words – Infrared Functional Imaging, microsurgery, cardio-surgery, sympathectomy, blood re-perfusion.

INTRODUCTION

Infrared Imaging (IR) allows the representation of the surface thermal distribution of the human body.

The availability of new generation of digital telethermographic cameras characterised by

- i) high spatial resolution;
- ii) temperature sensitivity;
- iii) very short acquisition time;

makes possible the use of IR to record functional processes that involve the control of the temperature of districts of interest (Infrared Functional Imaging, i.e. IRFI).

Several studies have been performed so far to assess the contribution that IRFI may give to the clinicians. Some of these regard the Raynaud's Phenomenon Secondary to Scleroderma (SSc) or chronic vasospastic syndromes [1].

Since IRFI devices permit to record real time temperature modifications without contact between the detectors and the subject, the information provided by IRFI could be used with twofold purpose in surgery applications:

- i) Valuation of re-perfusion processes during surgery (*thermo-angiography*);
- ii) Follow up of the modification of the neurovascular functions of the treated district by means of the study of thermoregulatory properties.

In order to evaluate the real advantages that IRFI could be provide to the surgeon, we have studied and performed IRFI assistance to cardiac surgery and microsurgery, for which the real time evaluation of the re-perfusion processes and the estimate of the recovery of the neurovascular functions constitute important information during the follow up.

MATERIALS AND METHOD

Instrumentation: IRFI measurements were performed using a 14-bit digital telethermographic camera AEG 256 PtSi, which spectral band is within 8-14 μm . The measurement noise was reduced to about 0.02 K. The integration time, i.e. the time to acquire each averaged thermographic image is 30 milliseconds. Images sizes were 256x256 pixels.

The camera was placed in the operating theatre at 1 m distance from the subject. Due to the optics of the camera, each pixel corresponded to 1 mm^2 . Black body correction was executed to avoid and correct instrumental artefacts, for each subject at the beginning and at the end of measurement session.



Fig. 1: IRFI intra-operating assistance to local sympathectomy. IRFI measurements are real time and not invasive.

IRFI test: The test consisted in recording 5 telethermographic images of hands at rest and other 40 during the re-warming period after cold thermal stress. The cold stress consisted in a 2minute immersion of both gloved hands in a cold bath at 10°C.

All patients had pharmacological washout during the week preceding the measurement and no vasoactive drugs for 24 hours before the test.

A 15 minutes acclimation period preceded the study session carried out in a measurement room with constant temperature ($T_0 = 23 \pm 0.5$)°C.

Re-warming curves were recorded for each of the five fingers of both hands [1].

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IRFI intra-operating assistance to cardio-surgery: The study has been performed on 3 male patients (range 60 -72 years), who underwent to coronary by-pass.

IRFI measurements were performed during the cardio-surgery operation to check the re-vascularization of the hearth after de-clamping of the bypass.

IRFI intra-operating assistance to local sympathectomy in chronic vasospastic syndromes and follow-up: Local sympathectomy in chronic vasospastic syndromes has been recently developed in solution of ischaemic phenomena of upper extremities [2-4]. In particular those situations such as arteriolar vasospasm in Raynaud's disease, unsuccessfully treated with medical therapy are considered.

The stereotypic patient is a young female in pre-menopausal age in whom vasospastic syndromes cause early appearance of digital ulcers and then partial or entire necrosis of a digital segment: The result is disability as well as the simple anaesthetic appearance.

The proposed microsurgical technique consists in the ablation of the vasospasm with the adventectomy of digital arteries injured by the ischaemic process.

IRFI intra-operating assistance was performed during sympathectomy in order to evaluate correct re-perfusion of the digital artery after adventectomy. While the microsurgical approach solves the degenerative processes, the effects induced by local sympathectomy on the thermoregulatory response have not been investigated. IRFI was therefore used to check possible thermal changes related to the adventectomy of digital arteries injured by the ischaemic process. The study has been performed on 3 patients, 2 females and 1 male (range 23 -30 years), with clinical history of systemic disease for 4 years and poor control of digital ischaemic symptoms.

The IRFI test was performed 2 days before and each 4 weeks after the sympathectomy.

Re-warming curves were recorded for each of the five fingers of both hands.

Moreover, we considered the thermal gradient after the 20 minutes of re-warming along the finger length. We calculated the slope of the gradient to re-normalise the data.

IRFI follow up of re-implantation of arm: The study has been performed on 3 male patients (range 27 -55 years), who underwent traumatic amputation of arm, with its complete detachment from the body. IRFI tests were performed each 4 months after the re-implantation.

Statistics: The IRFI data were analysed by means of the ANOVA test.

Ethics: All subjects gave informed consent to the study, which was approved by the local Ethical Committee.

RESULTS

IRFI intra-operating assistance to cardio-surgery: Figure 2 documents the re-vascularization of the hearth after de-clamping of the coronary bypass. The blood re-perfusion can be promptly assessed also in distal sites

IRFI intra-operating assistance to local sympathectomy in chronic vasospastic syndromes and follow-up: Figure 3

shown the re-vascularization after de-clamping of the digital artery during local sympathectomy. As example of the thermal changes induced by sympathectomy, we report the data of a patient which case can be considered as an average of the three ones studied.

IRFI evaluations permitted to document the absence of thermoregulatory control of the injured finger before sympathectomy. The evaluations following sympathectomy highlighted modest, but significant improving of the thermoregulatory capabilities of the treated finger. In fact, while the non-treated fingers do not substantially change their re-warming, the treated finger improves its recovery with a larger extension of the area interested by the re-warming. With regard to the slope of the gradient (Fig. 4), while normal fingers are characterised by a slope close to zero, the injured finger is characterised by slope values 0.17 before the treatment and 0.11 after the sympathectomy, respectively.

The slope of the gradient after treatment moves toward normal fingers behaviour. Moreover, the finger temperature is increasing toward normal fingers values.

IRFI follow up of the re-implantation of arm: IRFI evaluations permitted to document the absence of thermoregulatory control of the injured arms at the time of the first control (Fig. 5). The following evaluations highlighted modest, but significant improving of the thermoregulatory capabilities of the injured arm. This fact proved the slow and progressive restoration of the neurovascular functions.

DISCUSSION AND CONCLUSIONS

The preliminary results of the present study show that IRFI could be advantageously applied in the operating theatre for microsurgery and cardio-surgery. Thanks to its features – not invasiveness; real time availability of data; high temperature, spatial and time resolution – IRFI devices can provide useful information to the surgeon in order to control correct blood re-perfusion after de-clamping of the anastomoses. This aspect is particularly important to assume decisions or to choose strategies during the operation.

With respect to the capabilities to record and study thermoregulatory processes and documenting thermal modifications, IRFI could represent an elective tool to assess changes of neurovascular functionalities following re-implantation or sympathectomy.

Other standard investigative techniques (angiography and electromyography, for example) are invasive and not comfortable for the patient. Moreover, some of them cannot be used after surgery because of their invasiveness.

In conclusion, IRFI assistance in microsurgery and cardio-surgery is a powerful and useful tool available to the surgeon, both in the operating theatre and as follow up.

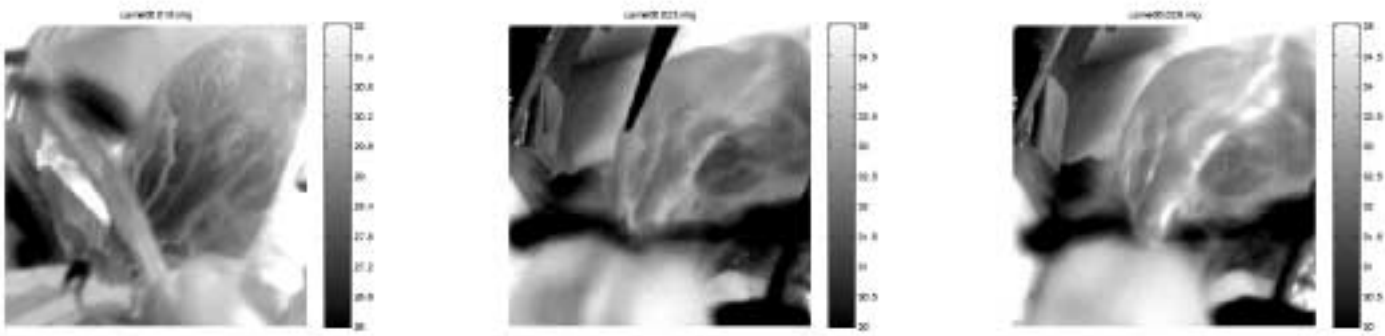


Fig.2: Coronary bypass. IRFI images document blood re-perfusion after de-clamping of the anastomoses. On the left, before the re-vascularization; on the centre and on the right, after the re-vascularization.

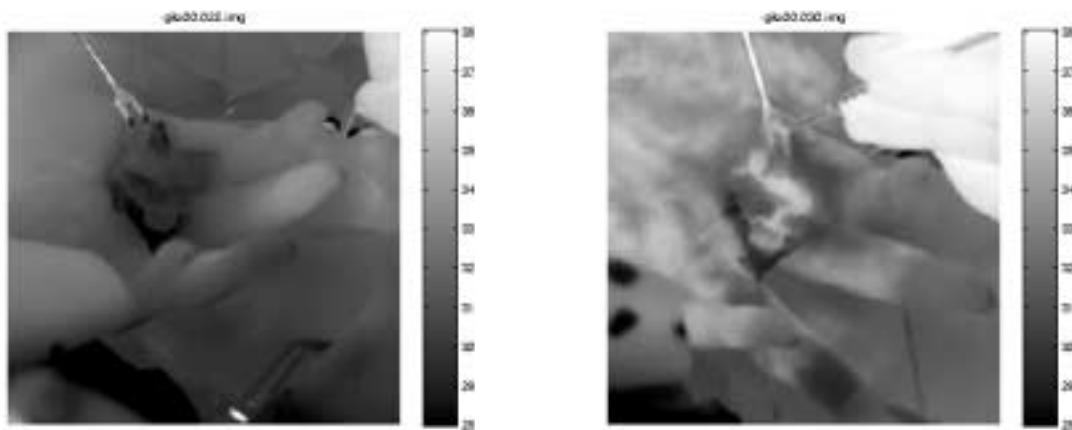


Fig. 3: Local Sympathectomy. On the left, before de-clamping of the artery; On the right, the blood re-perfusion causes the warming of the artery and its surrounding.

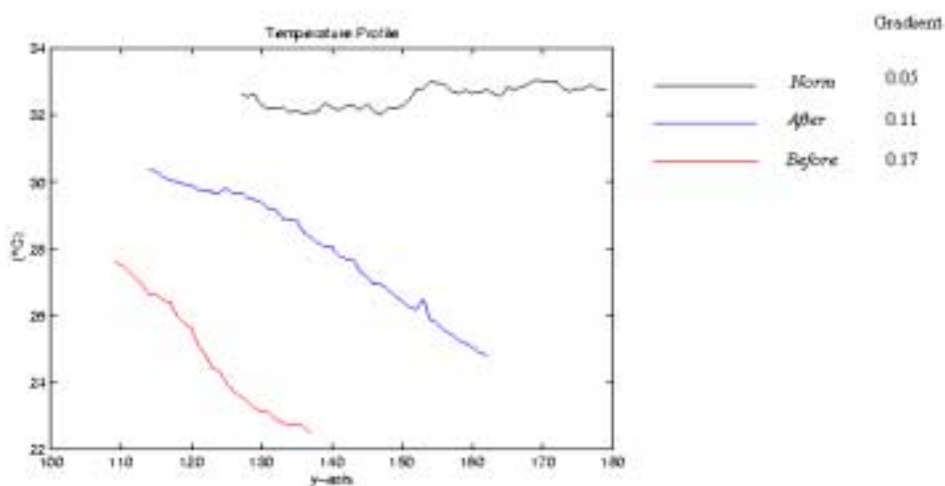


Fig. 4: Follow up for local sympathectomy . While normal fingers are characterised by a slope close to zero, the injured finger is characterised by slope values 0.17 before the treatment and 0.11 at the time of the first control after the sympathectomy, respectively. The slope of the gradient after treatment moves toward normal fingers behaviour. Moreover, the finger temperature is increasing toward normal fingers values.

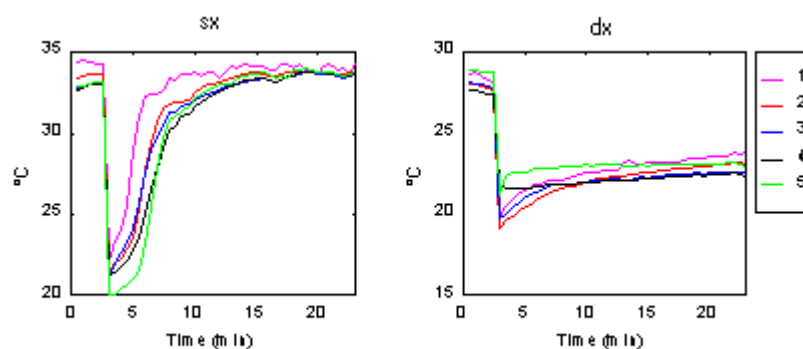
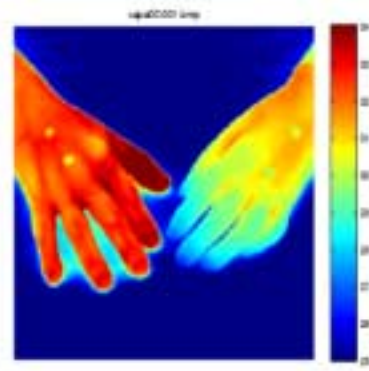


Fig. 5: Arm re-implantation . On the upper left, the image of the arm 10 months after re-implantation. The upper right IRFI image shows the thermal distribution of the hands 4 months after the operation. The bottom figure shows the modest thermoregulatory capabilities of the re-implanted arm with respect to contra-lateral at 4 months after re-implantation.

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Address for Correspondence: Dr Arcangelo Merla, Istituto Tecnologie Avanzate Biomediche, Università degli Studi di Chieti, Via dei Vestini 13, 66013 Chieti, Italy. Tel: +39 0871 3556952, Fax: +39 0871 3556930. E-mail: a.merla@itab.unich.it

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